OSCAR IPT/Bold Stroke Open Systems Lessons Learned

Prepared by the OSCAR IPT for:

Glenn T. Logan - Lt Col USAF

Open Systems Joint Task Force

Lessons Learned Agenda

0900-0915 Welcome (D. Weissgerber/J. Wojciehowski)

0915-1045 OSCAR Program (D. Weissgerber)

Early Expectations & Assumptions

Actual Experiences

1045-1100 Break

1100-1130 OSCAR Hardware (B. Abendroth)

1130-1145 Tools (C. Hibler)

1145-1200 Summary (D. Weissgerber)

1200-1300 Lunch

Lessons Learned Agenda

1300-1400 Bold Stroke

OASIS (D. Seal)

Cost Performance & Metrics (E. Beckles)

1400-1500 Open Discussions

1500 Closing Remarks (D. Weissgerber/J. Wojciehowski)

Boeing Open Systems Status

Products
- OC1.1 and OC1.2 OFPs

Status
- I-6 Flight Test

COTS
- DY-4 PowerPC Processor

OFP Architecture
- OOD / C++

Products
- H1, H2 and H3 OFPs

Status
- H1 Build 2 flight test - Aug

COTS
- DY-4 PowerPC Processor
- HI Image Processing
- Fibre Channel Network

OFP Architecture
- OOD / C++

Common Products
- HOL OFPs
- DOORS
- ROSE
- TORNADO (WindRiver)
- Gen Purpose Processor
- Image Proc. Module

Products
- COSSI AMC variant H/W
- Stage 1 functionality OFP

Status
- CDR upcoming

COTS
- DY-4 PowerPC Processor
- HI Image Processor

OFP Architecture
- OOD / C++

Products
- EMD OFP
- Suite 5 OFP

Status
- EMD Go-Ahead - May '00

COTS
- DY-4 PowerPC Processor
- HI Image Processor

BOLD STROKE

Boeing's Previous System Arch Lesson Learned Case Studies

- ***Software Modification/Maintenance Costs Are a Significant Recurring Investment***
- ***Must Break the Block Upgrade Paradigm Made Necessary by the Tight Coupling Between OFPs and Specific H/W Configurations***
- ***Assembly Language OFPs Have Become Increasingly Unstructured Through Many Upgrade Iterations***

OSCAR IPT Open System Lesson Learned Analysis

- ***Represents a Snapshot-In-Time***
  - ***Where We've Been***
  - ***Where We Are***
  - ***Where We're Going***

- ***Compiled by the Engineers Working the Issues***
  - ***Analysis of Key Impact Areas***

- ***Identifies Current Top 10 OSCAR Lessons Learned***

- ***Provides a Basis for Future Lessons Learned Comparisons/Analysis***

AV-8B OSCAR Principles

- ***Follow US DoD Directive For Acquisition Reform***
  - ***Apply Revised DoD Directive 5000 (dated 15 Mar 96)***
  - ***Commercial Business Philosophy***
  - ***Performance Based Specs vs Procurement Specs***
- ***Insert Commercial Technologies***
  - ***COTS Hardware***
  - ***COTS Software Development Environment***
- ***Reduce Life Cycle Cost***
- ***Apply Open System Architecture***
  - ***Emphasis on Non-Proprietary Hardware and Software***
  - ***Object Oriented Design and High Order Language***
  - ***Software Independent of Hardware***
- ***Increase Allied Software Development Workshare***

Review of Early Expectations

- ***OSCAR's Goals***
  - ***Reduce Life Cycle Support Cost of Software Upgrades (Cost Savings to be Realized during 3rd Block Upgrade)***
    - *Shortened OFP Development Cycle*
    - *Reduce Rework in Dev Cycle & DT/OT*
    - *Reduce Regression Testing in OC1.2 (OC1.1 set baseline)*
  - ***Leverage Commercial Technology***
  - ***Incorporate an Open Architecture Concept***
  - ***No Reduction in System Performance***

Review of OSCAR Open System Assumptions

- ***Implementation of Open Systems H/W and S/W Requires Up-Front Investment***
  - ***Recoupment Within** <u>**2-3 Updates**</u> **to the S/W***
- ***Open System Computing H/W is Based on Commercial Standards***
  - ***Promotes Competition***
  - ***Takes Advantage of Commercially Driven Requirements for Technology Insertion***
- ***LCC Analysis Shows a 30-40% Cost Reduction in Core Computing H/W and S/W Development but not necessarily applicable to System Integration/Test of Multi-Sys Block Upgrades***

Review of OSCAR Open System Assumptions (cont.)

- ***OSCAR and Open Systems Computing Does Not Affect Tasks Associated with the Airframe or Flight Qualification of New Weapons/Capabilities***

- ***Two-Level Maintenance Concept Philosophy Will Reduce LCC and Increase Operational Availability***

- ***OSA provides Arch for a Plug-and-Play Trainer Concept***

- ***With OSCAR as First Large Scale Implementation of Open Systems and Object Oriented S/W:***
  - ***Reluctance to Fully Realize the Cost Benefits Until OSCAR is Fielded and all the Data Collected and Analyzed***

Review of OSCAR's Open System Assumptions (cont.)

- ***OSCAR's Open System Architecture Will Make Incremental Upgrades Possible by Decoupling H/W and S/W (I.e., MSC-750-G4)***
- ***Commercial Off-The-Shelf Products can be Directly Incorporated with Minimal Development Costs***
  - ***Multi-Vendor Support Ensures Competitive Procurement Costs***
- ***Software LCC Savings are Derived from the High Degree of Modularity Envisioned***
  - ***Less Than Half the Regression Test and Re-Qual Effort of Today***

Data & Metrics Currently Collected

- ***SPI***
- ***CPI***
- ***Requirements -- System & software levels, stability index***
- ***SLOC -- Estimates vs. actuals, productivity factor***
- ***Classes***
- ***Peer Review***
- ***TWD -- Development & ground test execution***
- ***Flight Test -- flights, test points, analysis***
- ***Problem Reports - various flavors***
- ***Throughput & Memory Spare***
- ***Hardware Performance***
- ***Risk***

Initial Expectations for Metrics

- ***SPI -- Identify an immediate schedule problem***
- ***CPI -- Control overspending, identify underruns***
- ***System & Software Requirements -- Track the development to plan and identify any Growth***
- ***Requirements Stability -- Control requirements growth***
- ***SLOC Actuals vs. Estimated -- Control growth and 'gold-plating'***
- ***Software productivity (Manhrs/SLOC) -- Improve efficiency within which software is produced***
- ***Classes Actuals vs. Planned To Date -- Indication of performance to schedule***
- ***Peer Review -- Capture errors before the product is delivered***

Initial Expectations of Metrics

- ***TWD Development & Ground Test -- Readiness of test team to support system level test phase***
- ***Problem Reports -- Quality of the software & where are problems found***
- ***Throughput/Memory -- Keep software within the bounds of hardware performance***
- ***Risk -- Control risks & be prepared to act quickly if they materialize***

What Metrics Actually Provided

- **SPI -- Watch The Details**
  - *Lower level problems are masked within larger cost accounts*
  - *Top-level SPI can mask lower level account SPI difficulties*
  - *Provides good focus for the CAMs*

Overall Program Healthy

Critical Path Behind Schedule

OSCAR OC1.1 PERFORMANCE STOP LIGHT CHART

EEK ENDING: 27FEB00	TEAM	TEAM LEADER	SVdelta	CVdelta	SV	CV		SPI		CPI	ACI	BAC	EAC
GRAND TOTAL			348	554	[illegible]	[illegible]	⇧	99.2	⇧	105.7	214,236	350,916	367,343
OTAL CONVERSION (TDL01)	H00		268	483	(1,891)	11,065	⇧	98.9	⇧	106.9	159,936	266,193	279,950
AVIONICS SOFTWARE													
o WEAPON DELIVERY	[illegible]	HEZEL, K.C.	238	275	(326)	2,670	⇧	98.9	⇧	109.6	27,929	52,713	53,379
o PILOT/VEHICLE INTERFA	DMY	VOLLE, D.A.	5	(82)	(1,460)	[illegible]	⇧	96.2	⇩	93.2	39,280	54,123	60,305
o SENSORS & TARGET	DMX	SHYLANSKI, J.	(59)	21	(341)	4,025	⇩	98.4	⇩	123.9	16,835	38,356	43,943
o NAVIGATION & A/C STAT	DMU	REBHAN	(15)	81	9	414	⇩	100.1	⇧	102.8	14,721	20,292	23,558
o STF/DTE	DMT	BELL, R.T.	[illegible]	7	523	704	⇧	107.6		110.5	6,727	9,987	9,988
o SSEE	DMR	RUSSELL, W.H	0	(15)	0	(428)		100.0	⇩	91.0	4,766	9,166	10,866
o QUALITY	DMR	HIBLER, C.A	0	3	0	26		100.0	⇧	102.5	1,048	2,019	2,135
o SOFTWARE BULK	DMR	HIBLER, C.A.	0	0	0	2,969		100.0		137.9	7,836	10,805	8,668
TACTICAL ELECT WARFARE	DCA	MARX, J.A.	0	5	0	82		100.0	⇧	103.6	2,251	3,626	3,626
AVIONICS HARDWARE													
o MSC/CD	DEA	ABENDROTH	0	5	(10)	186		99.6	⇧	107.8	2,376	3,527	3,616
o WMC	DEA	SZCZUKA	0	(4)	(98)	425		97.9	⇩	110.4	4,080	6,396	6,397
INTEGRATION													
o EMC	DHF	GOODWIN	0	12	0	161		100.0	⇧	122.5	714	1,303	1,305
AVIONICS TEST	J00	ILGES, J.F.	70	173	(188)	1,285	⇧	98.8	⇧	109.4	13,655	21,701	21,367
LOGISTICS (Product Supt)	SK0	HERBERT, B.K.	0	7	0	63		100.0	⇧	107.8	800	2,038	2,038
DWG RELEASE	AB0	REARDON	0	1	0	673		100.0	⇩	177.5	868	2,031	1,356
SYSTEM ENGINEERING	BD0	WESTPHAL, J.L.	0	7	0	825		100.0	⇧	209.8	752	2,097	1,486
SAFETY/R&M	BD0	MCCOY, R.L.	0	(9)	0	484		100.0	⇩	136.5	1,325	3,211	2,630
MANAGEMENT	DMR	FRANKENFIELD, C.R	0	(40)	0	(387)		100.0	⇩	94.4	6,877	11,648	12,133
GENERAL BULK	DMR	RUSSO, A.G.	0	36	0	(448)		100.0	⇧	93.7	7,100	11,154	11,154
TAL [illegible]MRAAM (TDL02)	H00		86	44	47	1,251	⇧	100.1	⇧	103.2	39,432	62,602	65,343
AVIONICS SOFTWARE													
o WEAPON DELIVERY	DMW	HEZEL, K.C.	15	18	43	866	⇧	100.6	⇧	114.4	6,005	14,168	14,993
o PILOT/VEHICLE INTERFA	DMY	VOLLE, D.A.	0	44	0	(1,241)		100.0	⇧	86.5	9,213	9,271	9,775
o SENSORS & TARGET	DMX	SHYLANSKI, J.	0	22	0	(266)		100.0	⇧	97.3	9,891	15,150	17,669
o STF/DTE	DMT	BELL, R.T.	0	6	0	169		100.0	⇧	146.2	365	573	573
o SOFTWARE BULK	DMR	HIBLER, C.A.	0	0	0	545		100.0		153.9	1,010	1,555	1,093
INTEGRATION													
o EMC	DHF	GOODWIN	0	3	0	111		100.0	⇧	156.6	196	361	298
AVIONICS TEST	J00	ILGES, J.F.	71	(53)	4	940	⇧	100.1	⇩	114.0	6,696	11,294	10,896
LOGISTICS (Product Supt)	SK0	HERBERT, B.K.	0	3	0	30		100.0	⇧	111.2	265	567	609
AIR VEHICLE TECHNOLOGY	BAJ	BRIGULIO, J.A.	0	(12)	0	(91)		100.0	⇩	94.8	1,754	1,807	2,010
DWG RELEASE	AB0	REARDON	0	0	0	155		100.0	⇩	168.5	226	497	386
SYSTEM ENGINEERING	BD0	WESTPHAL, J.L.	0	1	0	288		100.0	⇩	152.1	552	1,422	1,032
MANAGEMENT	DMR	FRANKENFIELD, C.R	0	15	0	54		100.0	⇧	104.5	1,199	3,104	2,941
GENERAL BULK	DMR	RUSSO, A.G.	0	(2)	0	(307)		100.0		85.1	2,060	2,833	3,068
OTAL 1760B (TDL03)	H00		(6)	27	(14)	(15)		99.9	⇧	99.9	14,868	22,121	22,050
AVIONICS SOFTWARE													
o WEAPON DELIVERY	DMW	HEZEL, K.C.	3	45	154	507	⇩	107.2	⇧	128.3	1,790	5,907	5,019
o SOFTWARE BULK	DMR	HIBLER, C.A.	0	0	0	71		100.0		999.9	1	72	42
INTEGRATION													
o EMC	DHF	GOODWIN	0	6	0	33		100.0	⇧	122.8	143	448	449
AVIONICS TEST	J00	ILGES, J.F.	1	38	(17)	539	⇧	99.6	⇧	115.7	3,435	4,657	4,521
LOGISTICS (Product Supt)	SK0	HERBERT, B.K.	0	(9)	0	(212)		100.0	⇩	91.3	2,425	3,023	3,260
DWG RELEASE	AB0	REARDON	0	(1)	0	(221)		100.0		16.9	266	64	213
AIRFRAME/SUBSYSTEM	ACK	HOHL, K.L.	(11)	(50)	(151)	(622)	⇩	96.8	⇩	88.2	5,259	5,432	5,520

What Metrics Actually Provided

- ***CPI -- New functionality Costs More Than Legacy***

New Functionality

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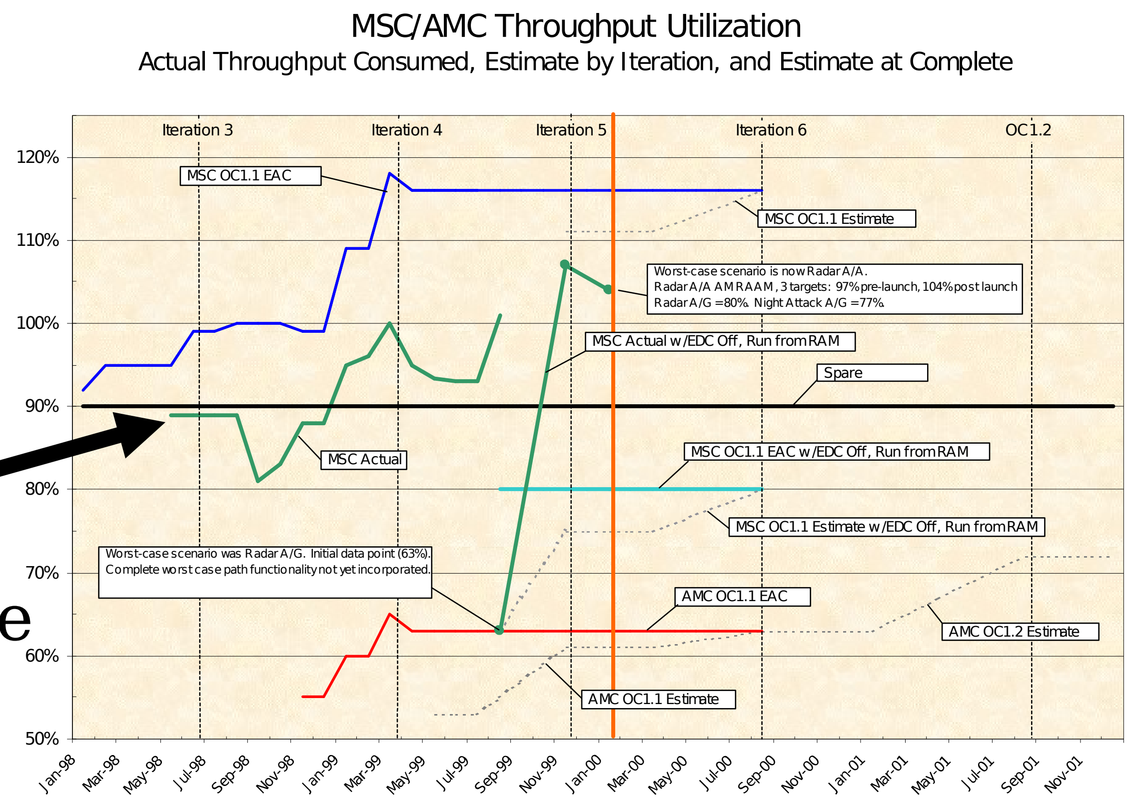
What Metrics Actually Provided

- ***System Requirements - No Changes Resulting From OO/C++ Development***
  - ***Level Of Detail & Complexity Commensurate With Assembly***
  - ***OO Makes Traceablity To Code Is Difficult (see other chart)***
- ***Requirements Stability -- good to show what's moving through the system, but don't really know how many requirements and corresponding code/tests are affected (traceability)***
- ***Risks -- hard to maintain a monthly review juggling schedules, but good tool to keep on top of issues, when High risks are identified - resources are focused on them***
  - *Engineers tend to set risks at HW/SW detail level and not see the top level System Functionality High Risks*

What Metrics Actually Provided

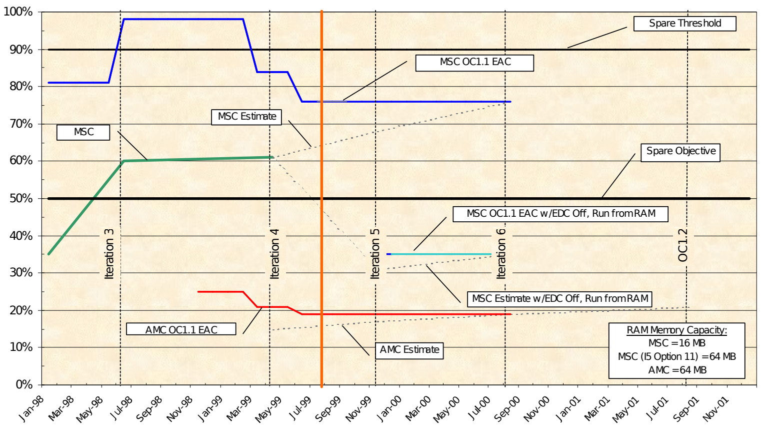
- **Throughput Usage**
  - *OO , COTS OS makes throughput consumption difficult to predict*



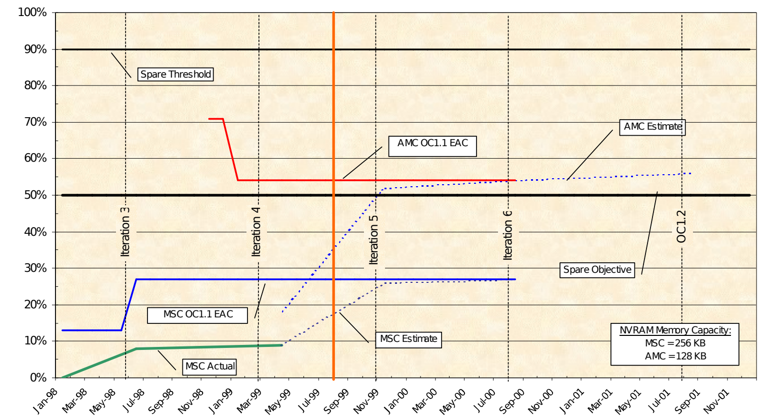
Predicted Usage

What Metrics Actually Provided

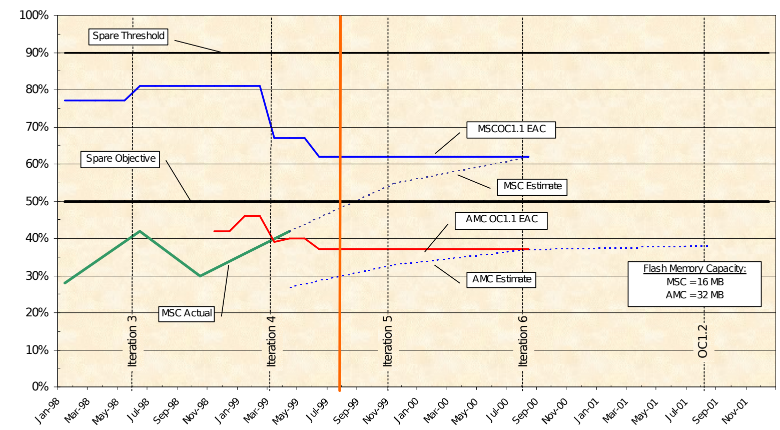
MSC/AMC RAM Memory Utilization
Actual Memory Consumed, Estimate by Iteration, and Estimate at Complete



MSC/AMC NVRAM Memory Utilization
Actual Memory Consumed, Estimate by Iteration, and Estimate at Complete



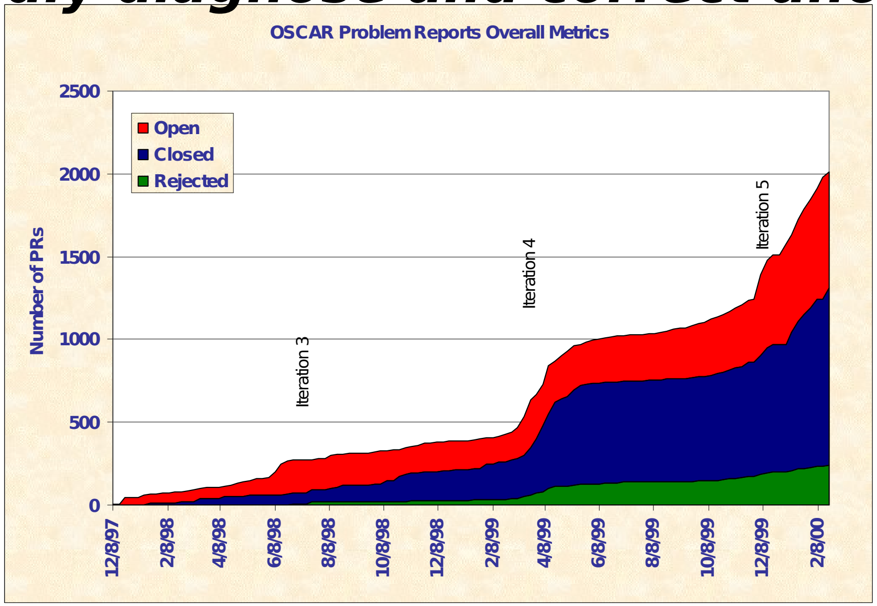
MSC/AMC Flash Memory Utilization
Actual Memory Consumed, Estimate by Iteration, and Estimate at Complete



- **_Memory Usage_**
  - **_Consumption can be predictably scaled from assembly language implementation_**

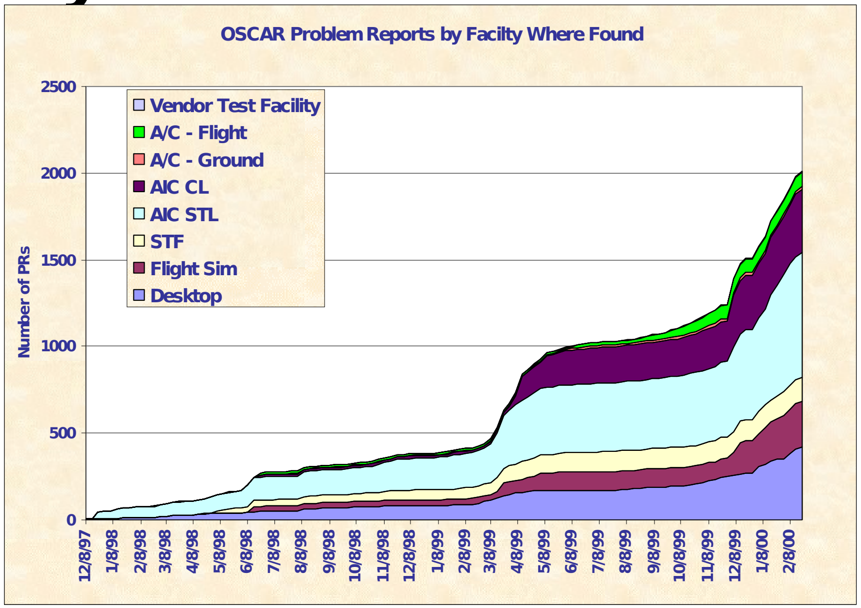
What Metrics Actually Provided

- ***Problem Reports -- Open/Closed/Rejected***
  - ***OO/C++ enables trained developers with Tools to rapidly diagnose and correct anomalies.***



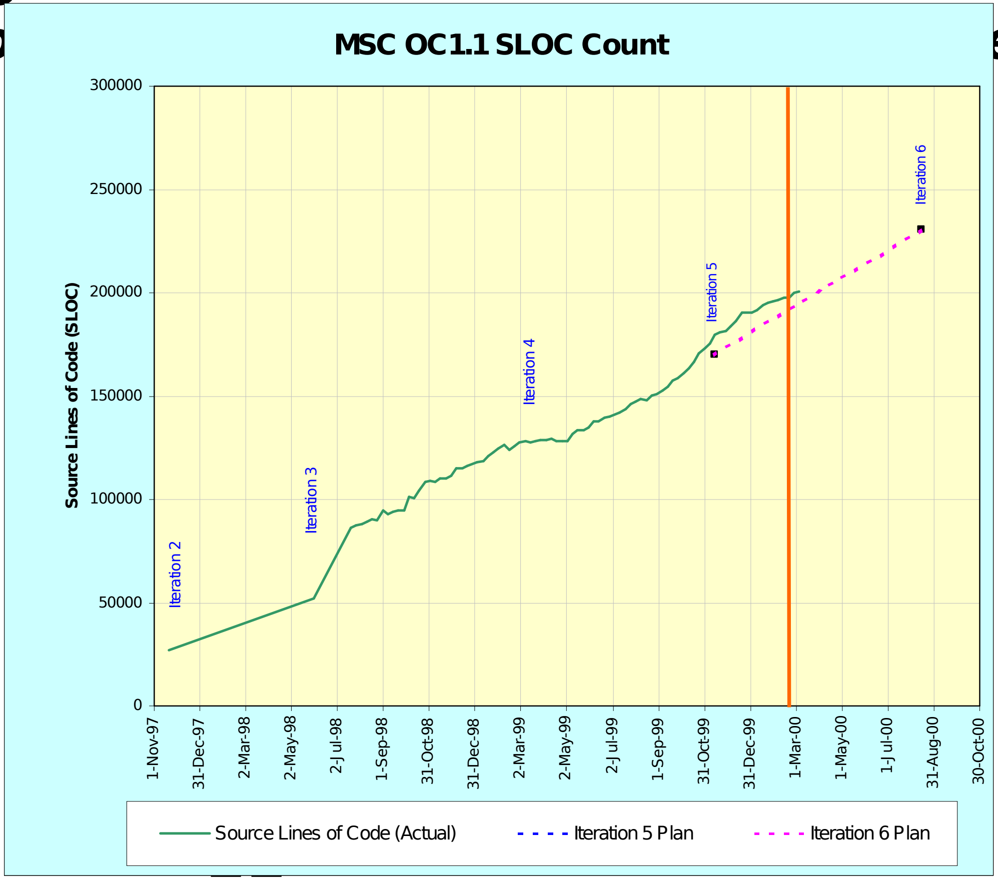
What Metrics Actually Provided

- **Problem Reports - Where Found**
  - DTE Saves Time & Money
  - Provides a "Software Test Facility" on every desktop
  - Less problems found in flight than Legacy OFP



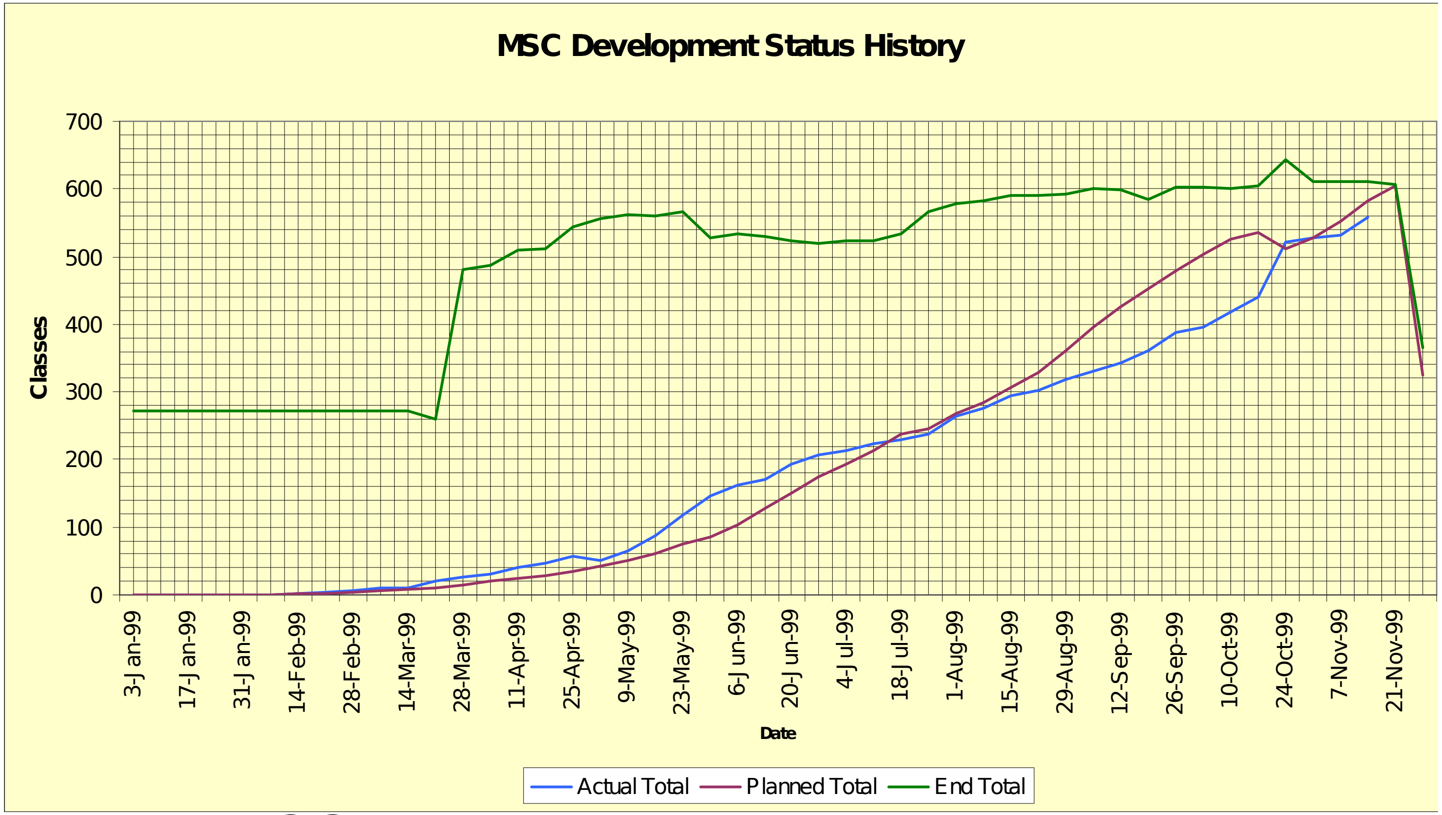
What Metrics Actually Provided

- ***SLOC***
  - ***Not very useful***
    - ***Some code “auto”-generated by 4th generation tools***
  - ***Poo*** … ***equired***



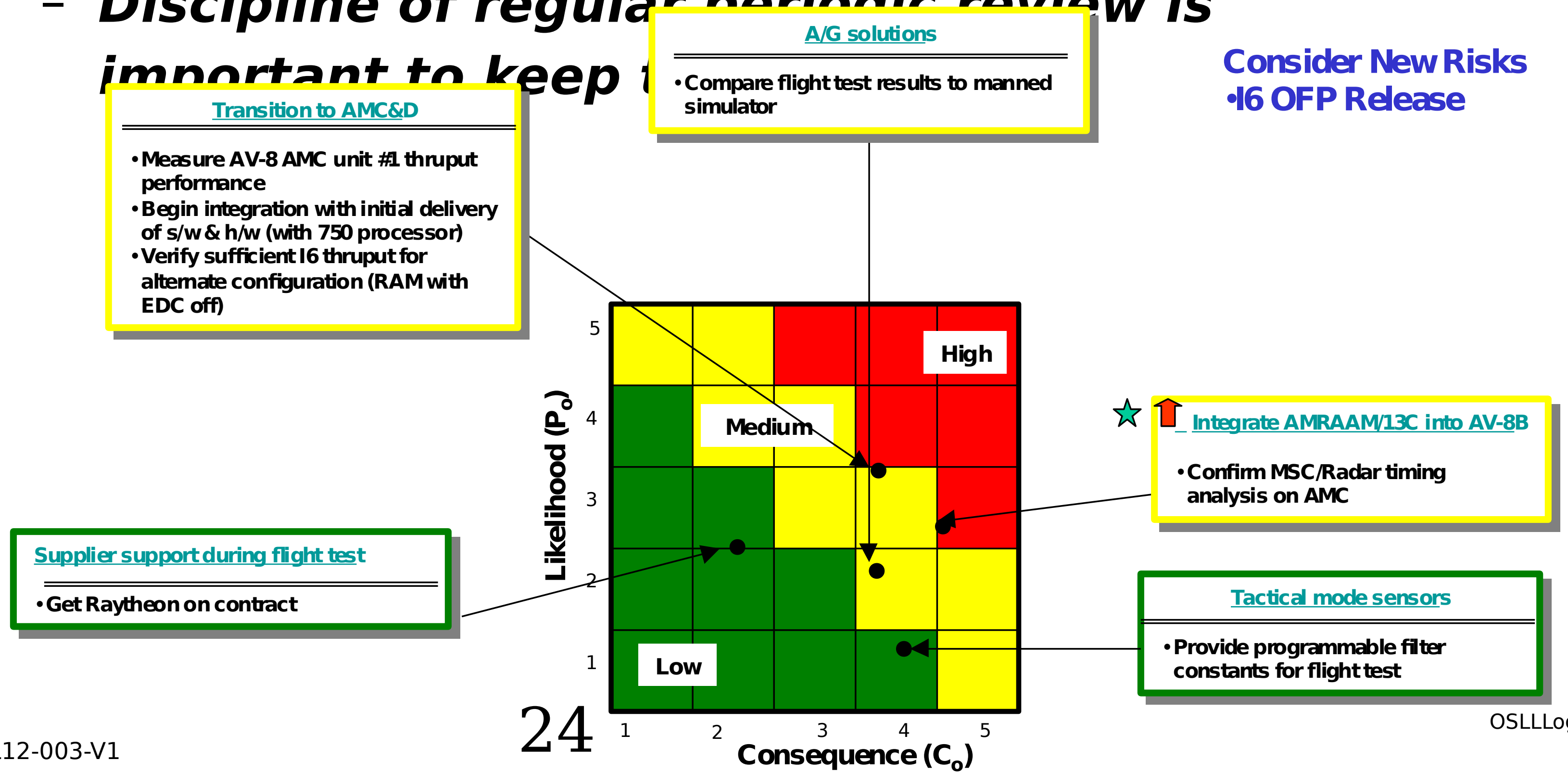
What Metrics Actually Provided

- ***Classes***
  - ***Best measure of development progress***
    - *Similar to function points*
    - *SLOC difficult to estimate*



What Metrics Actually Provided

- ***Risk***
  - ***Good tool to keep on top of issues but can bring too much Political help***
    - ***When high risks are identified -- resources are focused on them***
  - ***Discipline of regular periodic review is important to keep t***



Summary of OS Lessons Learned For Currently Collected Metrics

- ***SPI -- Watch The Details***
- ***CPI -- New functionality Costs More Than Legacy***
- ***System Requirements - No Changes For Assembly***
  - ***Traceablity To Code Is Difficult***
- ***TWD Development -- Same as in Traditional Development***
- ***SLOC count -- Not as Useful for OO/C++ Development Tracking***
- ***Classes -- Good Indicator of Development Progress***

Summary of OS Lessons Learned For Currently Collected Metrics

- ***Problem Reports - Total -- OO/C++ a Benefit to Problem Resolution***
- ***Problem Reports - Where found -- DTE Saves Time & Money***
- ***Throughput Usage - OO, COTS Makes Prediction Difficult***
- ***Memory Usage - Scaleable from Legacy Development***
- ***Risk - Good Tool to Focus Attention & Resources, if Risk Identification doesn't get too Political***

Technology Challenges

COTS supports the code/debug/unit test stages of development well but many <u>Voids</u> still exist:

- ***"Front end" of process***
  - ***Model-based tools for requirements/design capture***
  - ***Automated configuration and integration of components***
- ***"Back end" of process***
  - ***Simulation-based testing***
- ***Support for hard real-time embedded systems is limited***
  - ***Quality-of-service requirements expression/guarantees***
- ***Legacy system constraints***
  - ***Infusing new technology into resource-limited, "closed" systems***
- ***High Integrity System development technologies***

Cultural Challenges

- ***Acquisition culture presents impediments as well***
  - ***"Silo" approach to planning/funding system modernization***
  - ***"Wasn't invented here" mindset in programs***
  - ***Inability to trade front-end investment for life-cycle returns, even when business case is compelling***
  - ***Synergy with COTS industry will always be limited without cultural transformation***
  - ***Support structure based on single fielded configuration***
  - ***T&E community resistance to tailored re-qualification***

No incentive for multi-platform development

OSA Lessons Learned - Standards

Goal: Use Widely Accepted Commercial Standards

- Standardize Module Form, Fit, Function and Interface (F^3I) to Allow Functional Performance Upgrades
- USE COTS Standards for Networks, Processors, Memory, and Operating System

Reality: Existing Commercial Standards Do Not Typically Accommodate Aerospace Requirements

- Real Time Operation - Flight Dynamics
- Memory Partitioning for Fault Containment
- Built-In-Test

Solution: Modify Commercial Standards Through Active Participation in Standards Bodies

- ANSI Fibre Channel Avionics Environment (FC-AE)
- Modify Commercial STD Common Object Request Broker Architecture (CORBA) for Real-Time Operation
- Add Service Layers on Top of Commercial Software Infrastructure

OSA Lessons Learned - Specifications

Goal: Focus on Specifying Functional/Performance Requirements versus "How To"

- Use Commercial Specs Wherever Possible
- Use Tailored Mil-Specs
- Eliminate Unnecessary "How To" specs

Reality: It is Difficult to Prevent Engineers (Boeing, Customer, and Supplier) From Diving Down Into Too Much Detail

- Commercial Specifications may not match Aerospace requirements
- Additional effort needed to ensure Performance Levels and interoperability Are Achievable

Solution: Need to get a Better Handle on the High Level Performance Requirements

- Develop benchmark application program to validate memory and throughput for COTS processors
- Using a "Performance Prediction Team" to Conduct Simulation and Modeling of Key System Attributes.

COTS Lessons Learned

- ***COTS May Not Work As Well For Your Application As The Application For Which It Was Developed***
- ***COTS Frequently Has Surprises, Especially With Little Used Features***
- ***COTS Documentation May Be Lacking, Or Will Not Tell You How It Will Work In Your System***

Lessons Learned - Diagnostics

- ***Diagnostics Processes/Tools must better address False Alarm Rate***
- ***Supplier must better understand Total Diagnostics Requirements***
  - ***Fault Coverage***
  - ***Fault Isolation***
  - ***False Alarms***
  - ***Failure Reporting & Recording***
- ***Diagnostic System must have integrated on-board and off-board capability that can be updated in a timely manner***

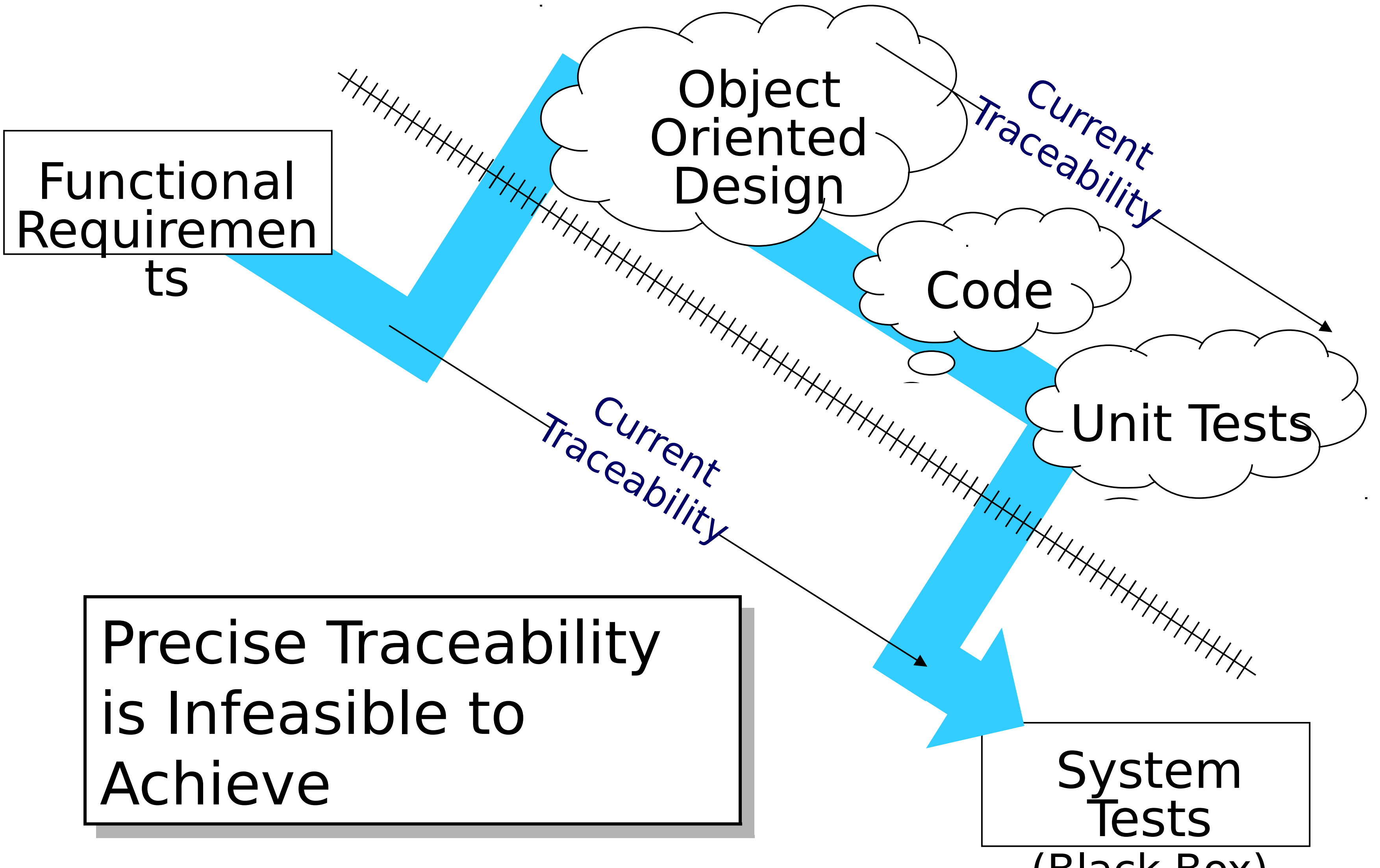
al System Diagnostics Architecture Must Minimize NFF Occurren

Lessons Learned - Prototyping

- **Early And Frequent Prototyping Required Throughout The Program**
- **Develop Software Incrementally Utilizing Daily Builds**
- **Complex Functionality needs to be partitioned and implemented early**
- **Verify Design And Ensure API's Meet Needs Of User**
- **Verify Software And Hardware Performing As Expected**

No New Lessons from Legacy Developments

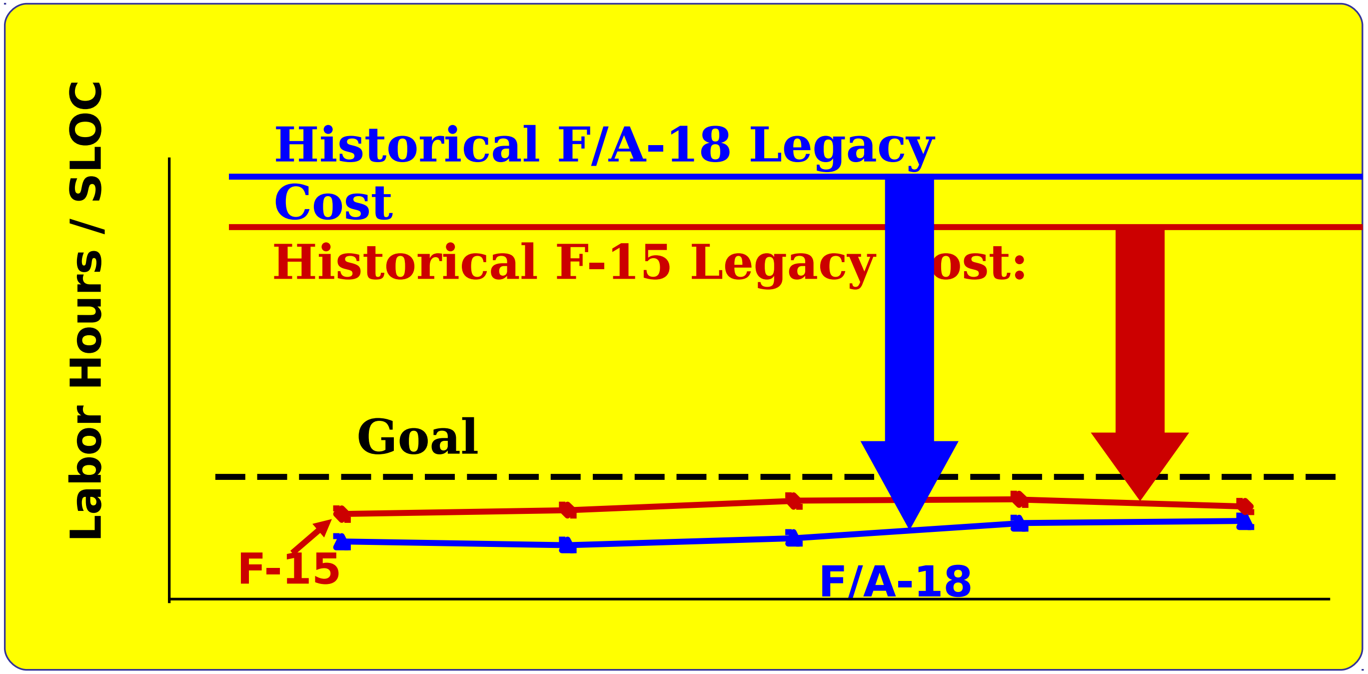
Object Oriented Design in a Functional Decomposition World



Precise Traceability is Infeasible to Achieve

Early Returns - Measured Benefit

Cumulative Software Development Productivity

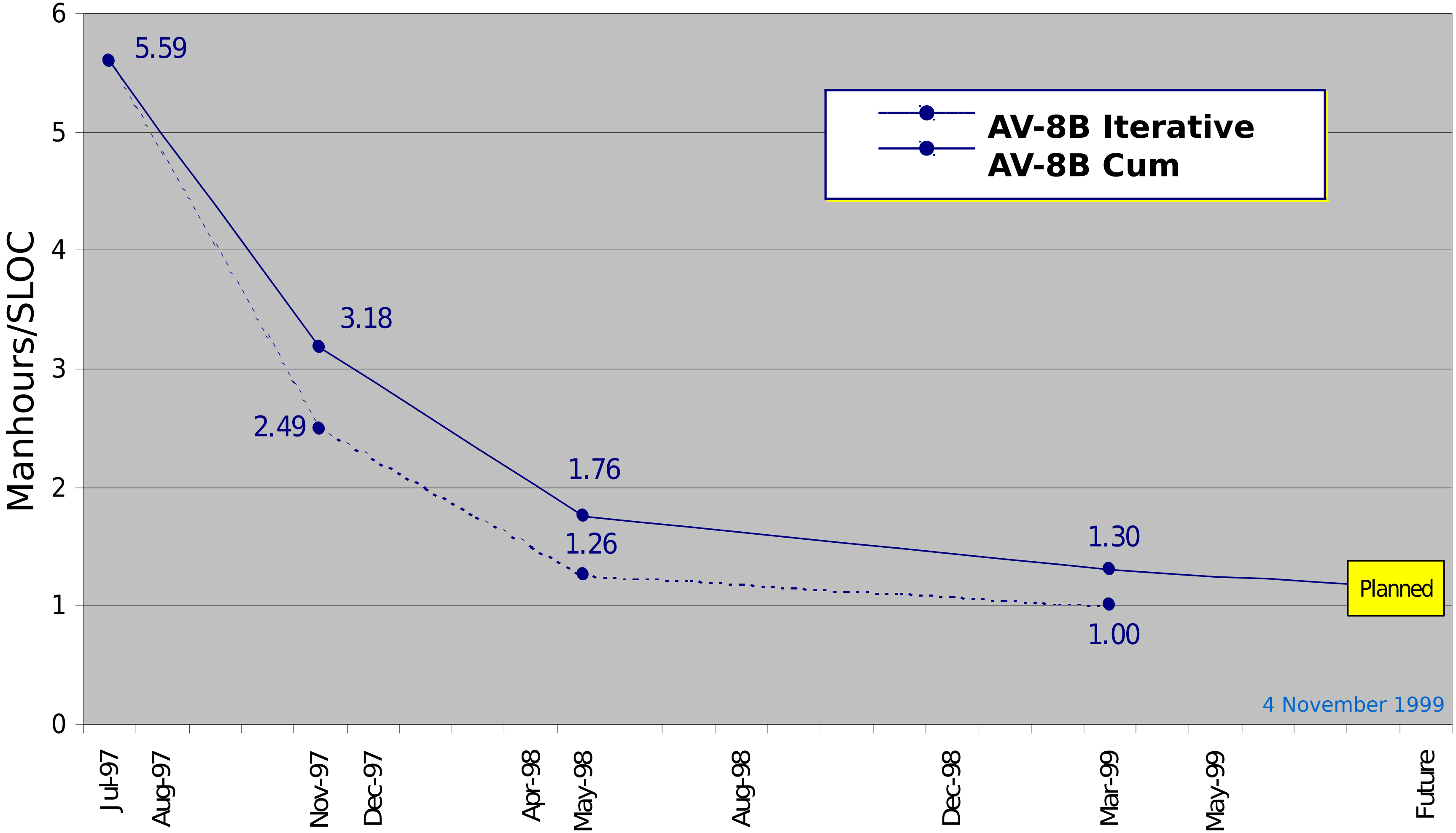


Key Sources of Gain:

- **Reuse (of all types)**
- **COTS Tools**
- **Change Containment**
- **Desktop Testing**
- **High Order Language**

Measured Software Development Affordability Improvement

S/W Development Productivity
(Hand plus Rose Generated Code)



Lesson Learned - OSCAR Hardware

Qual Test

- ***The following environmental qual tests have been completed :***

MSC & WMC

- **Temp-Alt**
- **Vibration**
- **EMIC**
- **Acoustic Noise**
- **Loads**
- **Shock**
- **Humidity**
- **Salt**
- **Exp Atmosphere**
- **Sand & Dust**

Qual Test Cont'd

- ***COTS hardware did Well.***
  - ***No problems with off-the-shelf DY-4 Processor board (one capacitor failure in RDT.***

- ***No problems with plastic parts (PEMS)***
  - ***Hardware with plastic parts were exposed to MIL-STD-810 Humidity and Salt-Fog environments in two WRA's with no failures.***
  - ***Was a major concern of some people early in the program.***

Reliability

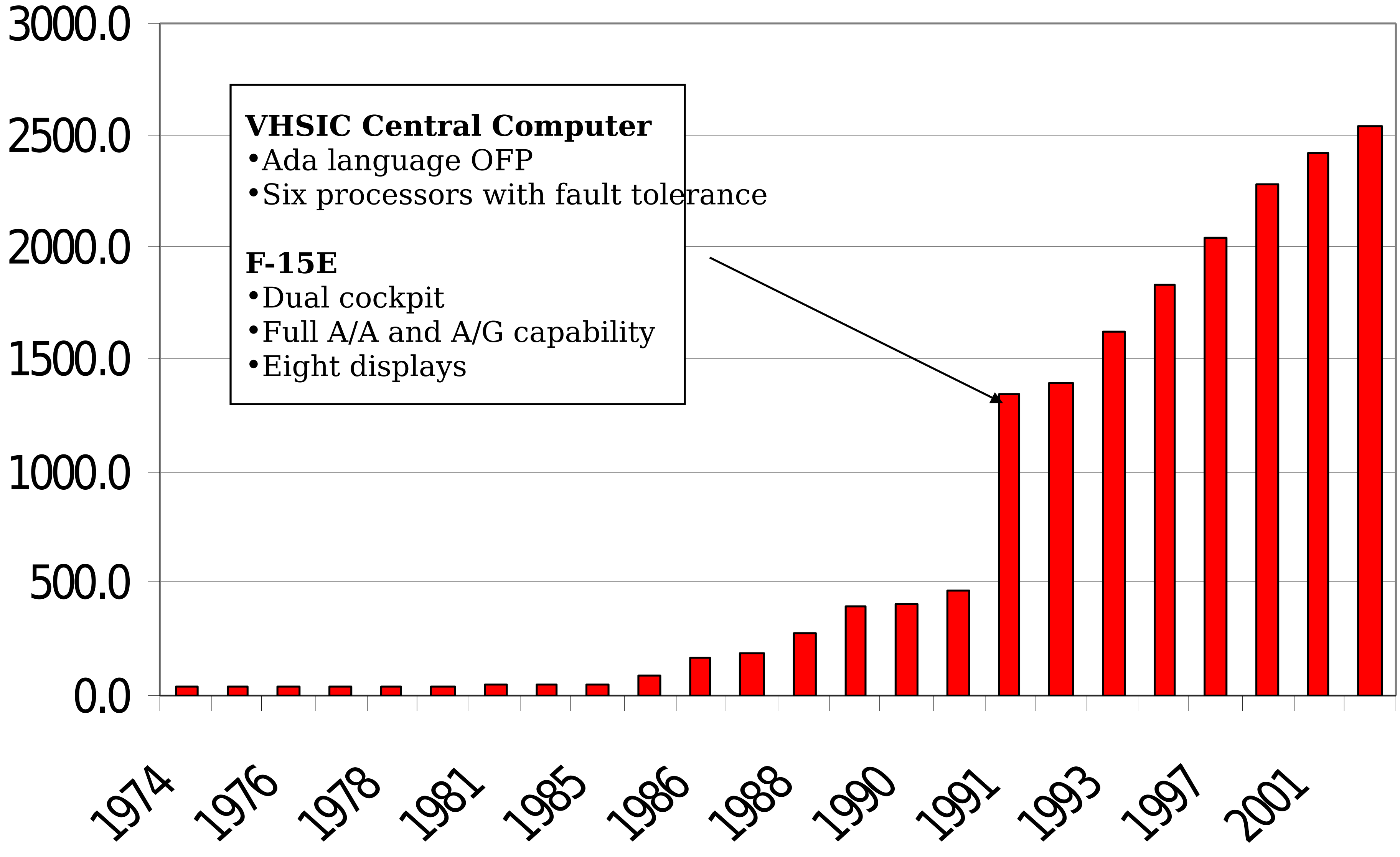
- ***Reliability experience to date with COTS hardware has been good.***
- ***Reliability Development Testing (RDT) done on three WRAs.***
  - ***WMC - 1,000+ hours***
  - ***MSC #1- 1,000+ hours***
  - ***MSC #2 - 1,000+ hours***
- ***One capacitor failure on COTS board, Root cause unknown.***
- ***One commercial grade capacitor failed on another SRA. Switching to a MIL-SPEC capacitor.***
- ***Other failures occurred, but unrelated to COTS hardware.***

Memory and Throughput

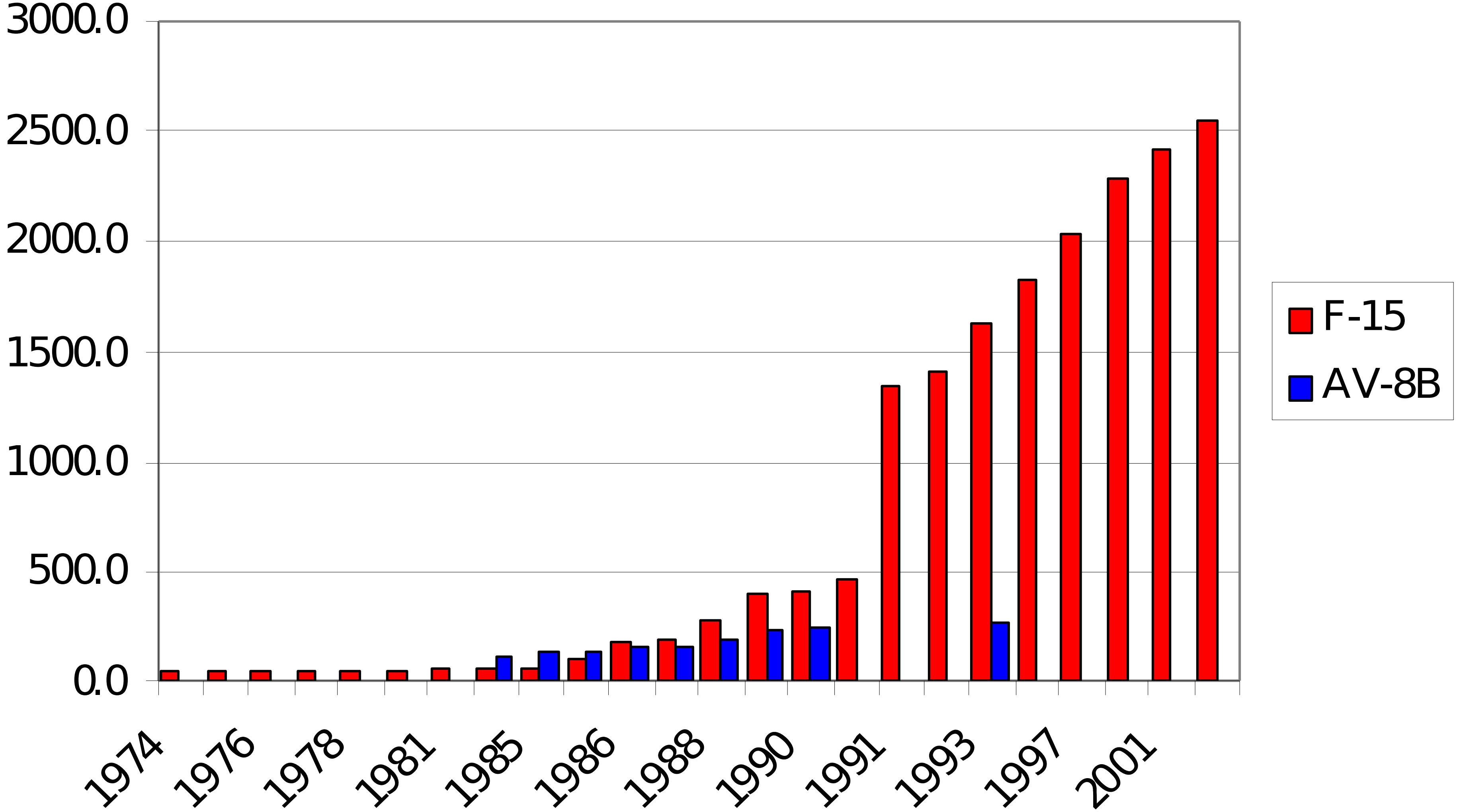
- OOD is a big resource consumer.
- The F-15 Central Computer OFP had already been converted from an assembly language to a HOL (Ada) in the early 1990's.
- Felt comfortable with initial OSCAR estimates based on complexity of the F-15 aircraft versus the AV-8B, a six processor solution (on the F-15) versus a single processor, and the continued growth in available throughput in commercial processors.

However, a 4x estimate turned into a 40x re

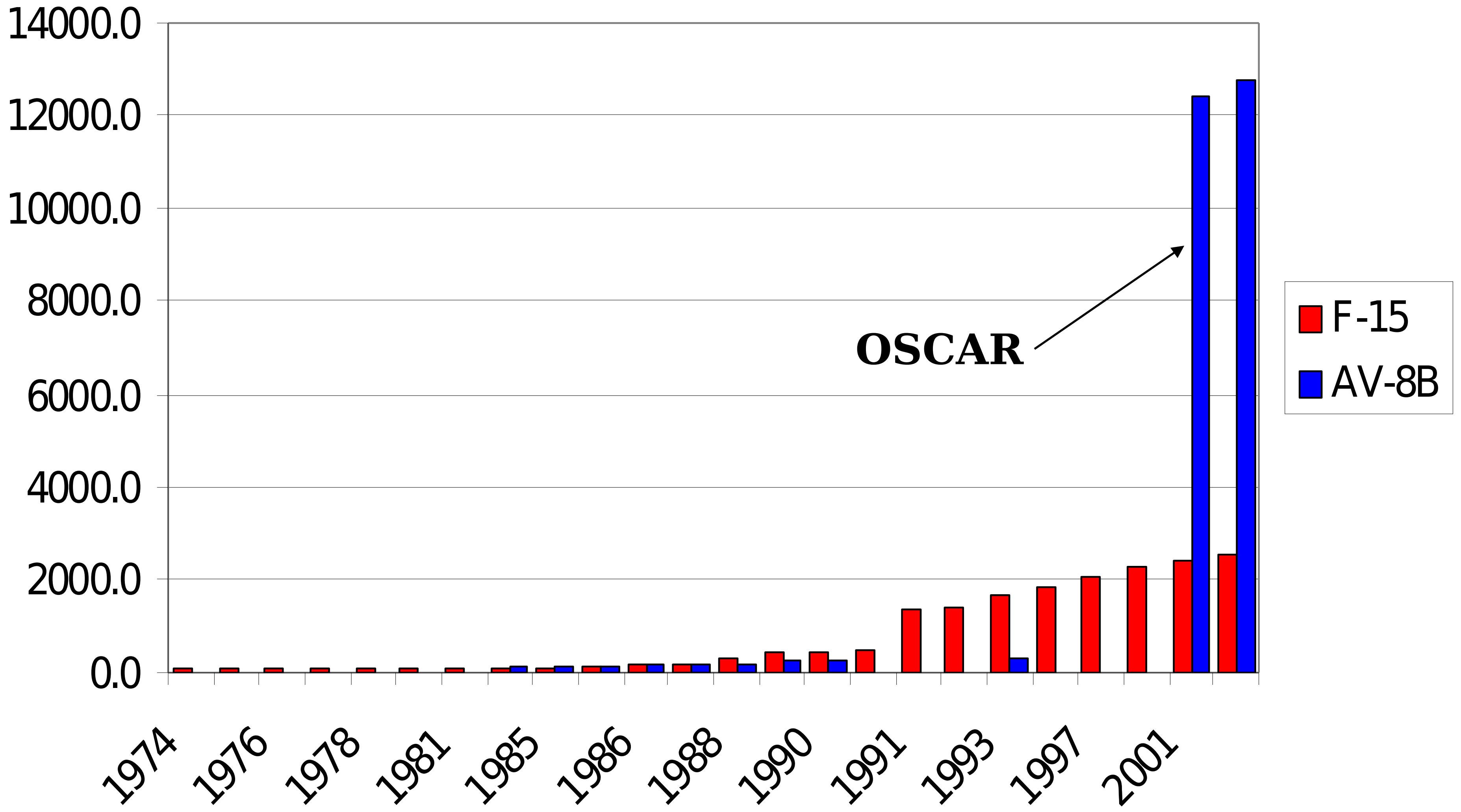
F-15 Mission Computer Memory Utilization



F-15 and AV-8B Mission Computer (pre-OSCAR) Memory Utilization



F-15 and AV-8B Mission Computer memory Utilization



Memory and Throughput Conclusions

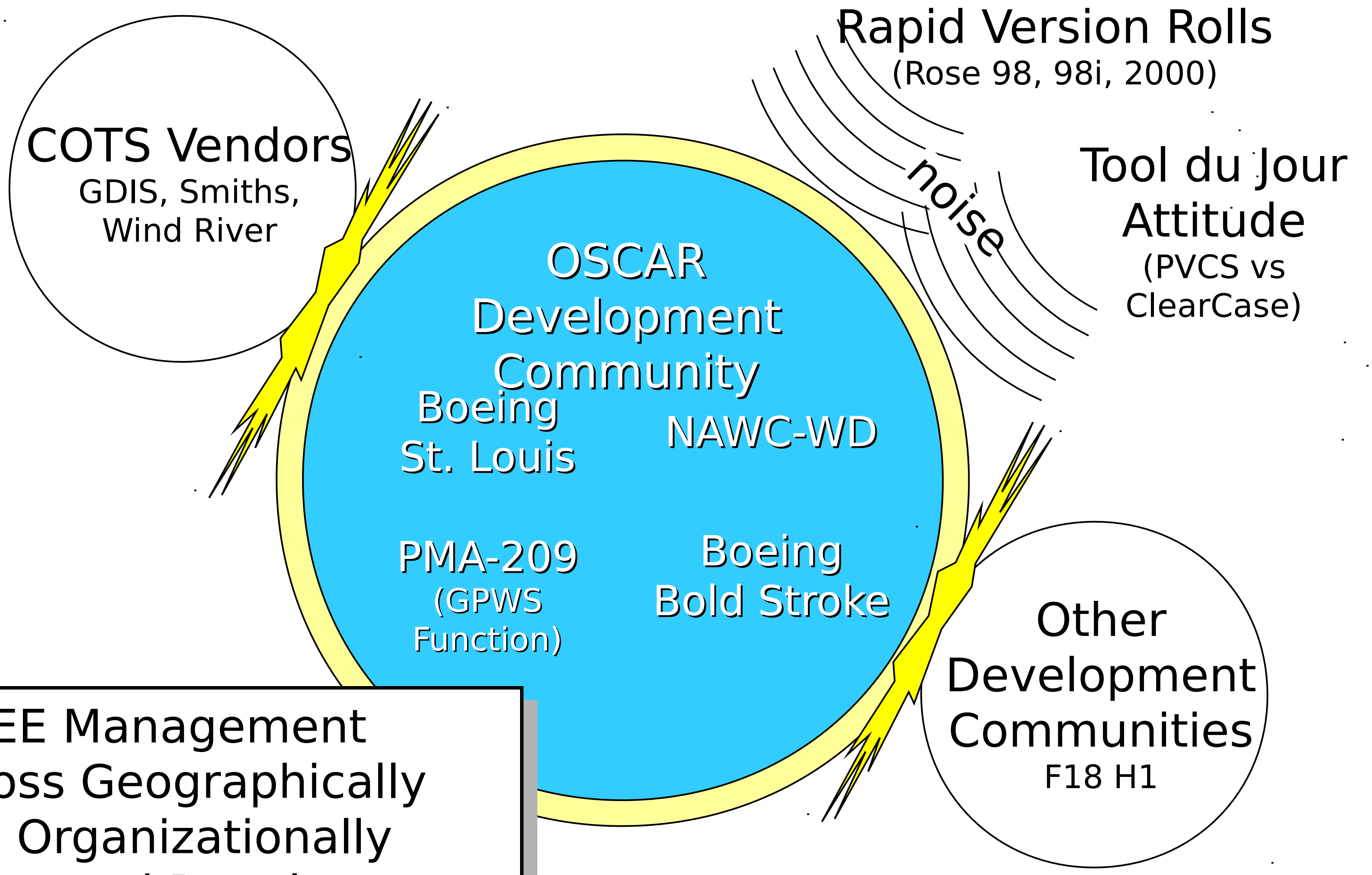
- ***Use of OOD has a tremendous impact on Memory usage.***
- ***Believe throughput impact is even greater, although more difficult to compare.***
- ***Lesson Learned - Use of OOD adds an order of magnitude (or more) to memory and throughput requirements.***

Tools Lessons

OSA Lessons Learned - Tools

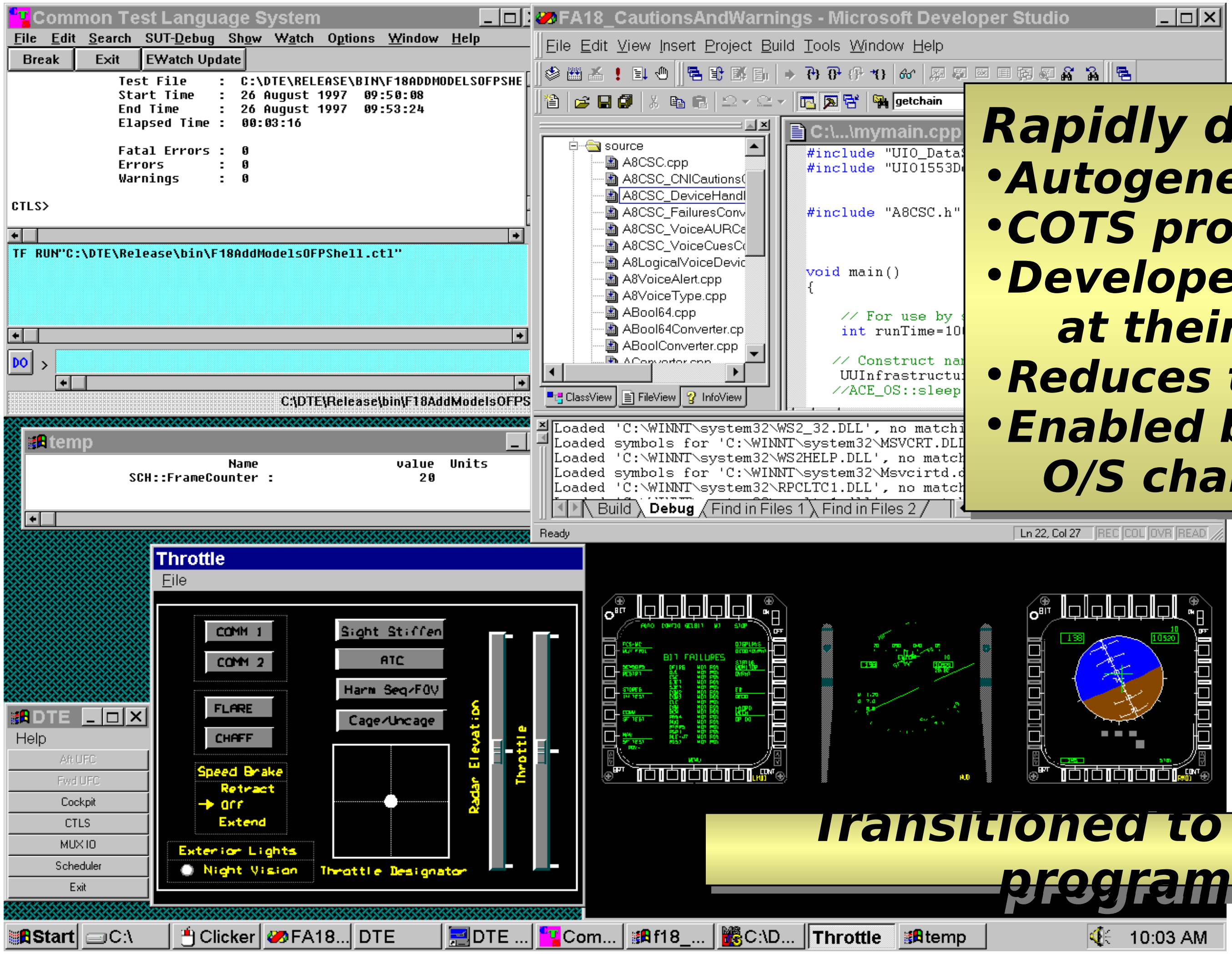
- ***Not All Commercial Tools Scale To Large Development Programs***
- ***Interoperability Of Commercial Tools Must Be Evaluated Prior To Selection***
- ***Keep Up With New Tool Versions To Maintain Vendor Support***
- ***Plan Tool Transitions***
- ***Utilize Dedicated Tool Engineers***

Tool Compatibility



S/SEE Management Across Geographically and Organizationally Separated Development Sites requires tight Tool CM

Desktop Test Environment



Rapidly design once
- ***Autogenerated code***
- ***COTS processors & tools***
- ***Developers run OFP at their desk***
- ***Reduces time and cost***
- ***Enabled by hardware an O/S change containme***

Transitioned to multiple programs

Summary

Lessons Learned Summary
(Most Critical)

- **COTS**
  - Use Existing Products
    - Don’t Push Technology, Follow It (Cost/Schedule\Risk)
    - Use Technology Rolls To Satisfy Growth, Not Baseline Requirements
  - DOD Programs Have Limited Influence On Commercial Developments
    - Very-Very-Small Quantities Compared to Industry
  - COTS Does Well In Qualification Testing

- **Open Systems Design**
  - Cultivate/Develop Multiple Production Sources Up Front
  - Partition Software Workpackages Along Functional Lines (Self Contained Packages)

Lessons Learned Summary (Cont.)
(Most Critical)

- **C++ / OO Design**
  - Throughput Is Difficult To Estimate
  - Scale The Software To the EXISTING Computer Resources:
    - Memory, Throughput, I/O
  - In Order To Reuse Functional Software The Top Level Requirements **MUST** Be The Same
  - Reused Software Will Require Significant Rework
  - Process & Procedures Are No Substitute For A Stable, Well-Trained Workforce
  - Troubleshooting Transient Problems Is More Difficult in COTS Environment
  - Turnaround On Fixes Is Much Quicker

- **Functionality**
  - Document And Bound All Requirements
  - Limit New Functionality Until After Legacy Is Complete
  - Be Selective in Legacy Problem Fixing During Conversion

- **Use Multiple Metrics To Identify Problems**

Priority Order of the Top 10 OSCAR Lessons Learned

1 -- Document And Bound All Requirements

2 -- Reused Software Will Require Significant Rework

3 -- Process & Procedures Are No Substitute For A Stable Well Trained Workforce

4 -- Throughput Is Difficult To Estimate (OO)

5 -- Use Existing Products (COTS)

6 -- Use Multiple Metrics To Identify Problems

7 -- DOD Programs Have Limited Influence On Commercial Developments

8 -- Troubleshooting Transient Problems Is More Difficult

9 -- In Order To Reuse Functional Software The Top Level Requirements MUST Be The Same

10-- Partition Software Workpackages Along Functional Lines - (Self Contained Packages)

Summary

- ***How Are We Doing with Respect to Earlier Expectations?***
  - ***LCC savings and schedule improvements will not be realized until 2nd and 3rd upgrades***
  - ***Thruput estimates were off by an order of magnitude***

- ***Where Are We Going with the Open Systems Approach?***
  - ***Boeing Company roadmap for all legacy and future A/C system upgrades***

- ***Where Are We Going with Metrics Collection?***
  - ***Classes planned-vs-actuals is the best metric for program progress indicator***
  - ***Will continue to collect thru OC1.3 to set baseline***

- ***What Are We Going to "Do" with Lessons Learned Metrics?***
  - ***Compare to legacy systems metrics(where available) and produce / quantify data to establish baseline for F/A-18 & JSF systems development***
  - ***Incorporate lessons learned into Boeing-wide training programs***

The Next Step

Answer 5 Questions (Based On OSCAR Experiences)

1 -- How Fast Can The Investment Costs Be Recaptured?
2 -- Is OO/C++ Software Transparent To Hardware?
3 -- What is the Ratio Of New Functionality Development Costs Of OO/C++ vs. Assembly
4 -- Does OO/C++ Software Reduce Retest?
5 -- Is COTS Less Expensive?

The Next Steps - Develop A Plan

Develop A Plan/Process to Collect/Generate Data* that will Support the Determination of:

1 -- Actual Cost Of OSCAR Software Conversion

- *Use As Basis For Determining Investment Cost*
- *Factor Out New Functionality*
- *Requirements through Fleet Release*
- *Compare Against Original Estimates*
  - *If Different, Why?*

2 -- Actual Cost Of New Hardware (WMC / AMC)

- *Development Of Boxes*
  - *Use As Basis For Determining Investment Cost*
- *Unit Production Costs*
- *Compare Against Predictions*
- *Compare Against Dedicated Mil Spec. Box (Non-COTS)*

3 -- Was COTS Less Expensive?

- *Why or Why Not?*

***Note: Some Data May Not Be Available Until After The Completion Of OC1.1 & AMC**

The Next Steps - Develop A Plan

Develop A Plan/Process to Collect/Generate Data* that will Support the Determination of:

4 -- Actual Costs Of new Functionality

- *AMRAAM/13C (OC1.1)*
- *JDAM, HQ/SG (OC1.2)*

5 -- Comparsion With Assembly Language Version

- *Was It Cheaper to Develop? To Test?*
  - *Why?*

6 -- "Will OO & C++ Cause Less Retest In Subsequent OFPs?"

- *How?*
  - *Generate An OC1.2 Metric To Measure Unplanned Fixes To Legacy Caused By New Functionality*

7 -- Costs Associated With Migrating OSCAR OFP To New Processors

- *603e to 750*
- *750 to G4*
- *Was Hardware Transparent to Applications OFP?*
  - *If Not then Why?*
  - *Identify Issues*

***Note: Some Data May Not Be Available Until After The Completion Of OC1.1 & AMC**

The Next Steps - Determine the Pay Back

- *Using*
  - *The Initial Investment Costs*
  - *Follow On New Development Costs*

- *Determine*
  - *How Much Software Must Be Written To Pay Back Initial Investment*

Bold Stroke Open Systems Lessons Learned